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On Ancient Eclipses. By P. H. Cowell.

One of the most striking features of Mr. Nevill's recent paper (*Monthly Notices*, lxvi. pp. 404–420) is that, whereas I maintain that the ancient eclipses can only be satisfied by one set of formulæ for the configuration of the node, Sun, and Moon, he produces four systems, and states, on p. 415, that they respectively satisfy, out of twelve eclipses, seven or possibly nine, seven or eight, six at least, but possibly eight, and ten. A moment's consideration will show that Mr. Nevill and I must be using the word "satisfy" in different senses. He is evidently more easily satisfied than I am. On p. 416 he regards as satisfactory any value of $\Delta\phi$ less than $2\frac{1}{2}^\circ$; translating this into my language he is satisfied if the tabular latitude of the Moon, corrected for the difference of parallaxes at the moment of apparent conjunction in longitude, is less than $130''$—for shortness I will say if the residual is less than $130''$. Now the whole point of my first paper on eclipses (*Monthly Notices*, lxv. pp. 861–867) is that the residuals can be simultaneously reduced to less than $50''$. Mr. Nevill therefore uses the word "satisfy" with its stringency relaxed in the proportion of 5 : 2; it is no wonder, therefore, that so vast a number of mutually exclusive systems give him this very moderate amount of satisfaction. The same considerations explain Mr. Nevill's treatment of the eclipse of Utica. On p. 867 (*Monthly Notices*, lxv.) I give as the equation arising from this eclipse

$$+23s_F - 38s_D = +39''$$

where s_F, s_D are the corrections to the secular accelerations of the argument of latitude and mean elongation as adopted in my calculations.

The present tables imply, to those who believe in their accuracy, that $s_F = -4''$; we should then have

$$+23\,(s_F + 4'') - 38 s_D = +131''$$

Therefore I say that because I want residuals less than 50″ the eclipse of Utica is evidence in favour of my formulæ as against the present tables. Mr. Nevill, however, would be satisfied by the new residual. He therefore naturally considers (*Monthly Notices*, lxvi. p. 415) that "the epoch" (of the eclipse of Utica) "is so late that it cannot be regarded as of any value."

Again a very slight inspection of the five equations of condition on p. 867 (*Monthly Notices*, lxv.) will show that they can only be satisfied, in my sense, by small corrections to the secular accelerations adopted by me.

In exhibiting more eclipse calculations, I have had to decide whether to adopt a secular acceleration for the Sun in my formulæ or a secular acceleration of the node contrary to gravitational theory. I have preferred the former course, but I wish it to be clearly understood that the ancient eclipses only afford evidence of the relative movements of the Sun, Moon, and node, and not of the position of the equinox. Mr. Nevill's statement

Lunar Eclipses.

Ref. No.	T.	T².	T³.	*g*.	ω.	−Ω.	L′.	π′.	L
1	−25·197527	634·92	−15998	248° 26′ 34″	118° 32′ 47″	189° 45′ 16″	350° 29′ 36″	236° 25′ 39″	177°
2	−25·187833	634·43	−15980	194 24 7	176 44 49	208 30 17	339 29 1	236 26 38	162
3	−25·182991	634·18	−15971	344 59 42	205 49 3	217 52 14	153 47 57	236 27 8	332
4	−24·196615	585·48	−14167	161 49 17	7 49 15	325 45 50	24 1 21	238 7 54	203
5	−23·214281	538·90	−12510	209 50 12	145 32 4	65 50 6	108 44 2	239 48 15	289
6	−23·000838	529·04	−12168	184 27 20	346 59 44	118 41 6	232 49 55	240 10 4	52
7	−22·896527	524·25	−12004	281 28 45	253 15 13	320 26 50	28 6 4	240 20 44	214
8	−21·809918	475·67	−10374	49 22 29	296 58 34	262 12 21	266 47 23	242 11 48	84
9	−21·805057	475·46	−10367	209 2 8	326 9 37	271 36 29	81 47 21	242 12 18	263
10	−21·800209	475·25	−10361	2 29 34	355 16 0	280 59 7	256 19 15	242 12 47	76
11	−19·992410	399·70	− 7991	121 3 4	48 46 3	177 41 6	178 21 52	245 17 38	352
12	−19·987530	399·50	− 7985	289 46 44	78 3 55	187 7 26	354 2 52	24 18 7	180
13	−19·982709	399·31	− 7979	70 21 7	107 0 32	196 26 56	167 36 27	245 18 37	340
14	−19·726393	389·13	− 7676	343 54 39	205 50 58	332 13 20	35 9 56	245 44 51	217
15	−19·398950	376·32	− 7300	359 9 22	11 42 42	245 34 14	303 20 49	246 18 19	125
16	−16·747069	280·46	− 4697	72 22 51	92 39 29	334 53 23	12 57 43	250 49 43	190
17	−16·666218	277·76	− 4629	134 20 51	218 3 22	131 16 21	43 39 21	250 57 58	221
18	−16·651653	277·28	− 4617	244 44 31	305 29 54	159 26 40	208 0 24	250 59 29	30
19	−16·637903	276·82	− 4606	326 13 11	28 2 53	186 2 23	343 0 59	251 0 53	168

in his footnote to p. 417 (*Monthly Notices*, lxvi.) is perfectly correct; it is true that V−V′ may be altered by about 300″; but in forming the residual V−V′ has to be multiplied by the small quantity that I have called k, and the product is generally small. I have therefore substituted for the formulæ on p. 863 (*Monthly Notices*, lxv.) the following:

$$g = 110^\circ\ 19'\ 38'' + 171791\ 5794\mathrm{T} + 49''\cdot8\mathrm{T}^2 + 0''\cdot050\mathrm{T}^3$$
$$\omega = 192\ \ 7\ \ 25 + 2161\ 1516\mathrm{T} - 45\ \cdot4\mathrm{T}^2 - 0\ \cdot044\mathrm{T}^3$$
$$-\aleph = 326\ 43\ \ 39 + 696\ 2921\mathrm{T} - 7\ \cdot6\mathrm{T}^2 - 0\ \cdot007\mathrm{T}^3$$
$$\mathrm{L}' = 279\ 54\ \ 29 + 12960\ 2766\mathrm{T} + 5\ \cdot2\mathrm{T}^2$$
$$\pi' = 279\ 29\ \ 47 + \qquad 6186\mathrm{T} + 1\ \cdot6\mathrm{T}^2 + 0\ \cdot012\mathrm{T}^3$$

No other formula has been altered; the solar eclipse calculations of this paper are therefore sufficiently explained in my previous paper.

It is an unfortunate fact that in a large number of cases I am unable to agree that the quantities that Mr. Nevill has published in the fourth column of his paper under the heading "Cowell" represent my formulæ. To assist anyone who wishes

Ref. No.	V−L.	V′−L′.	V−V′ +180°.	U.	$\frac{d}{dt}(\mathrm{V}-\mathrm{V}')$.	$\frac{d\mathrm{U}}{dt}$.	μ.	$\Sigma = p+p'-\sigma$.	Δ = Least distance of centres.
1	−17280″	+6628″	+361″	+ 758″	1541″	+155″	916″	2410″	718″
2	− 5042	+7101	−765	+3091	1424	+146	886	2298	3154
3	− 4095	−7286	+105	−2912	1861	−184	1003	2721	2887
4	+ 5358	+4025	+814	+2777	1431	−146	887	2311	2845
5	− 8343	−5421	− 34	−2180	1445	+147	891	2323	2167
6	− 1168	− 951	−454	+2780	1414	−145	885	2273	2721
7	−17969	+3817	+478	+3189	1669	−165	949	2540	3220
8	+13491	+3090	+880	−3022	1773	+176	980	2625	3095
9	− 8386	−2388	+477	+2217	1445	−147	890	2325	2255
10	+ 674	+1811	+495	− 618	1867	+185	1005	2715	665
11	+15862	−6727	+158	+1876	1507	−152	908	2368	1882
12	−17765	+6816	−560	+ 976	1701	+168	958	2563	1025
13	+17624	−7117	+637	− 660	1698	−168	958	2555	595
14	− 5660	+3616	−735	−2619	1865	−184	1002	2734	2678
15	− 1096	+6148	−223	+3407	1869	+185	1005	2722	3412
16	+16777	+6026	+625	+3149	1692	−167	957	2564	3194
17	+12572	+3237	+246	−1306	1477	+149	899	2357	1325
18	−15668	−4987	−640	−1817	1523	−154	914	2384	1872
19	−10624	+7188	+950	−2652	1825	+181	992	2684	2732

to form an independent opinion on this point, I again publish in nearly the same form as in *Monthly Notices*, lxv. p. 866, what I may call the stepping-stones of my calculations, and I publish one calculation *in extenso*, selecting the eclipse of −708 July 17, where I can only believe that Mr. Nevill has made an error. If, therefore, anyone should suspect an error in my calculations, it should be excessively easy to demonstrate its existence.

In the calculations relating to solar eclipses the same reference number is used when more than one eclipse is worked up in connexion with the same record, and small letters are used in addition to the reference number in order to distinguish between the alternatives. Chinese eclipses are marked with capital letters instead of numbers.

T is the time in Julian centuries from 1800 Jan. 0·0 G.M.T. New Style, or 1799 Dec. 20·0 G.M.T. Old Style.

g, ω, $-\Omega$. L′ . π' are calculated according to the formulæ given in this paper; $L = g + \omega + \Omega$, the Moon's mean longitude.

V−L, V′−L′, are the inequalities of longitude of the Moon and the Sun. The formulæ employed are given in *Monthly Notices*, lxv. pp. 861–7.

V−V′, U are the difference of true geocentric longitude of the Moon and Sun and the geocentric latitude of the Moon.

Ref. No.	Date.	ΔT in units of Julian century ÷ 10^8 = $0^m.53$.	ΔT_1	Semi-duration ΔT_2 in minutes.	G.M.T. of middle of eclipse (tabular).	Observed *minus* tabular time. beginning.	middle.	end.
				m	h m	m	m	m
1	−720 Mar. 19	−23	− 5	111·3	7 35·2	[−85]		
2	−719 Mar. 8	+54	−22	15·9	9 52·4	...	+34	
3	−719 Sept. 1	− 6	−16	66·8	5 53·8	−49		
4	−620 Apr. 21	−57	+20	54·1	14 58·0	−23		
5	−522 July 16	+ 2	+15	86·4	9 25·5	...	+14	
6	−501 Nov. 19	+31	+19	59·9	9 50·8	−29		
7	−490 Apr. 25	−29	+20	42·4	8 21·2	...	+ 6	
8	−382 Dec. 22	−50	+18	55·1	17 36·0	?		
9	−381 June 18	−33	+15	83·7	6 52·6	−21	...	− 8
10	−381 Dec. 12	−27	+ 4	103·4	8 35·3	+ 4		
11	−200 Sept. 22	−10	+12	93·8	5 24·7	−28	...	−34
12	−199 Mar. 19	+33	− 6	104·4	11 26·3	−13		
13	−199 Sept. 11	−37	− 4	107·6	12 55·9	−30	−34	
14	−173 Apr. 30	+39	−15	73·7	12 6·4	− 5	...	+11
15	−140 Jan. 27	+12	−18	42·4	8 22·6	+27		
16	+125 Apr. 5	−37	+19	46·1	7 9·4	+ 3		
17	+133 May 6	−17	+ 9	106·0	9 13·9	...	− 6	
18	+134 Oct. 20	+42	−12	93·8	9 14·6	...	−29	
19	+136 Mar. 5	−52	+15	71·0	13 54·4	...	+10	

$\frac{d}{dt}(V-V')$, $\frac{du}{dt}$ are the changes of $V-V'$ and U in one millionth of a Julian century or 53 minutes of solar time.

$p-p'$ is the difference of parallax.

The place for which parallactic displacements are calculated is then set down, together with its assumed longitude and latitude; next follow the date and the local mean solar and sidereal times.

v', u' are the parallactic displacements in longitude and latitude calculated for the Sun's place with the difference of parallaxes. The subsequent columns explain themselves or are explained in *Monthly Notices*, lxv. 861–7, and the residual is the difference of apparent latitude at apparent conjunction in longitude, the positive sign indicating that the Moon is apparently south of the Sun. Finally the equation of condition is set down.

The calculations for lunar eclipses begin as in the case of solar eclipses; subsequently μ, $\Sigma = p+p'-\sigma$, Δ are the semi-diameters of the Moon and shadow, and the least distance between their centres.

$\mu = 0{\cdot}273 \times$ Moon's parallax.

$\sigma = 960'' + 16'' \cos g'$; $p' = 9'$

Ref. No.	Observed magnitude.	Tabular magnitude.	Observed *minus* tabular magnitude. (*a*)	(*b*)	Observed *minus* tabular magnitude with allowance for increment of Earth's shadow. (*a*)	(*b*)	Corresponding corrections to assumed secular acceleration.	
							"	"
1	total	1·42						
2	3 digits = 0·25	0·02	+0·23					
3	more than half	0·42	+0·09 ?	...	+0·07		−2·4	
4	0·25	0·20	...	+0·05	...	+0·03	...	+1·1
5	0·5	0·59	...	−0·09	...	−0·11	..	−4·4
6	0·25	0·25	...	0·00	...	−0·02	...	−0·8
7	2 digits = 0·17	0·14	...	+0·03	...	+0·01	...	+0·4
8	small	0·26						
9	—	0·54						
10	total	1·52						
11	partial	0·77						
12	total	1·30						
13	total	1·52						
14	7 digits = 0·58	0·53	+0·05	...	+0·03	...	−1·6	
15	3 digits = 0·25	0·16	+0·09	...	+0·07	...	−4·0	
16	0·17	0·17	—	0·00	...	−0·02	...	−1·5
17	total	1·07						
18	[0·33]	0·78	−0·11 ?					
19	0·50	0·48	...	+0·02	...	0·00	...	0·0

Δ = latitude of Moon at conjunction in longitude as inferred from the values of $V-V'+180°$, U, $\frac{d}{dt}(V-V')$, $\frac{du}{dt}$ and diminished by one half per cent., to represent multiplication by the cosine of the inclination of the Moon's orbit.

ΔT = interval from the instant chosen for calculation to the instant of conjunction in longitude.

ΔT_1 = interval from conjunction in longitude to the middle of the eclipse.

ΔT, ΔT_1 are expressed in units of a Julian century $\times 10^{-8}$ = 0·53 solar minutes

$$\Delta T = 100\,(V-V'+180°) \div \frac{d}{dt}(V-V')$$

$\Delta T_1 = \Delta \div \frac{dU}{dt}$, the sign of ΔT_1 being negative if U and $\frac{dU}{dt}$ are of the same sign. To obtain this formula 100 times squared sine of the inclination of the relative orbit is taken as unity.

ΔT_2 is the semi-duration of the eclipse in solar minutes; the semi-chord of the eclipse is $\sqrt{\{(\Sigma+\mu)^2-\Delta^2\}}$. This is turned into time by dividing by $\frac{d}{dt}(V-V')$, diminishing the quotient by

Solar Eclipses.

Ref. No.	T.	T^2.	T^3.	g.	ω.	$-\Omega$.	L′	π'.
				° ′ ″	° ′ ″	° ′ ″	° ′ ″	° ′ ″
1*a*	−29·225902	854·15	−24963	315 30 27	52 45 17	317 50 55	46 12 53	229 34 23
1*b*	−29·154776	850·00	−24782	56 41 48	119 47 17	95 25 30	86 47 57	229 41 39
1	−28·613889	818·75	−23428	46 55 40	127 13 5	61 38 33	119 6 7	230 36 50
2	−25·615143	656·14	−16807	42 51 29	131 15 23	101 58 53	76 1 37	235 43 0
A	−25·074254	628·72	−15765	34 5 31	138 39 13	68 11 41	108 24 25	236 38 15
3	**−24·775033**	**613·81**	**−15207**	**233 10 23**	**134 45 28**	**236 50 45**	**78 24 40**	**237 8 48**
4	**−24·594795**	**604·90**	**−14877**	**231 2 58**	**137 13 52**	**275 35 12**	**89 15 53**	**237 27 13**
5*a*	−24·082222	579·95	−13966	29 57 14	334 36 44	187 1 40	182 15 3	238 19 34
5	−24·015912	576·76	−13851	352 57 56	12 43 23	315 17 15	49 27 25	238 26 22
B	−23·992474	575·64	−13811	17 32 13	153 26 23	0 37 20	173 14 29	238 28 45
6	−23·835614	568·14	−13542	350 50 43	15 11 33	304 1 39	60 18 40	238 44 46
6*a*	−23·555862	554·88	−13071	287 59 46	254 45 39	125 8 6	51 34 43	239 13 21
7	−22·293794	497·01	−11080	264 35 54	271 54 44	46 16 34	126 54 46	241 22 20
8	**−22·022948**	**485·01**	**−10681**	**271 49 57**	**98 0 3**	**210 9 21**	**157 33 35**	**241 50 1**
9	**−21·984961**	**483·34**	**−10626**	**39 9 44**	**326 3 53**	**283 37 53**	**85 7 6**	**241 53 53**
10*a*	**−21·624371**	**467·61**	**−10112**	**32 4 42**	**330 57 1**	**261 5 50**	**106 36 46**	**242 30 46**
10*b*	**−21·596051**	**466·39**	**−10072**	**226 19 59**	**140 58 32**	**315 52 28**	**46 9 9**	**242 33 39**
11	−21·083482	444·51	− 9372	23 22 5	338 17 47	227 18 7	138 59 56	243 26 4
C	−20·984025	440·33	− 9240	324 4 35	215 24 29	59 40 29	119 31 17	243 36 14
D	−19·864262	394·59	− 7838	73 3 31	98 7 40	65 33 7	111 47 1	245 30 44
E	−19·797951	391·96	− 7760	36 33 19	136 14 16	193 48 45	339 1 36	245 37 31
12	−16·025461	256·82	− 4116	262 33 23	104 54 19	290 37 57	71 22 12	252 3 35

one half per cent., and the unit changed to solar minutes by multiplying by 53.

Hence $$\Delta T_2 = 52{\cdot}7 \sqrt{\{(\Sigma+\mu)^2-\Delta^2\}} \div \frac{d}{dt}(V - V').$$

The Greenwich mean time of the middle of the eclipse is found by turning $T+\Delta T+\Delta T_1$ from Julian centuries into hours and minutes.

The next three columns give the observed *minus* tabular times; the observed times are taken without change from Professor Newcomb, except that the position of the observers of eclipse No. 8 is considered unknown; the phase observed is sometimes uncertain; that which I have assumed is indicated by the heading.

The next two columns give the observed and tabular magnitudes; the tabular magnitude being calculated from the formula $\frac{1}{2}+\frac{\Sigma-\Delta}{2\mu}$; the difference is entered in column *a* or column *b*, according as a displacement of the Sun relatively to the node in the forward direction would decrease or increase the magnitude of the eclipse; in other words column *a* corresponds to cases

Ref. No.	V−L.	V′−L′.	V−V′.	U.	$\frac{d}{dt}(V-V')$.	$\frac{dU}{dt}$.	$p-p'$.
1*a*	−12853″	+ 423″	+1840″	+1475″	1799″	+177″	3595″
1*b*	+15650	−4373	− 639	− 224	1756	−173	3553
1	+13882	−6805	−3068	+ 709	1788	−177	3585
2	+12807	−2493	+1282	+ 743	1804	−178	3601
A	+11070	−5673	+2861	+1367	1828	−181	3626
3	−14173	−2599	−1948	+1269	1497	+150	3304
4	−13705	−3783	+2423	+1432	1490	+150	3298
5*a*	+ 9414	−6141	−1410	+2195	1833	+181	3635
5	− 2471	+1116	− 188	+1590	1875	+185	3672
B	+ 6435	−6698	+2740	+2347	1857	−184	3659
6	− 2758	− 196	+3555	+1670	1873	+185	3670
6*a*	−17280	+ 952	+3524	+ 626	1696	−167	3495
7	−17124	−6569	+1403	+2644	1599	−159	3408
8	−17330	−7259	−2447	+1486	1625	+162	3437
9	+11803	−2812	+1933	+2669	1816	+179	3613
10*a*	+10040	−4982	−1831	+1772	1835	+181	3631
10*b*	−13237	+2012	+3775	+1213	1479	+149	3283
11	+ 7780	−6998	−1913	+1110	1850	+182	3650
C	−10147	−5943	−3166	+1185	1823	−180	3624
D	+17981	−5157	+1001	+1248	1690	−167	3491
E	+10254	+7223	+2865	+1225	1818	−180	3622
12	−17967	+ 84	+1602	+ 805	1594	+159	3396

when the Moon is partially eclipsed on its south limb at the ascending node or on its north limb at the descending node, and column *b* to the two remaining cases.

In this paper I will begin with the discussion of the lunar eclipses first.

An error of 1″ in the secular acceleration of the mean elongation will produce an error of $T^2 \div 30$ minutes in the tabular time, a quantity that varies from 21 minutes for the first eclipse to 9 minutes for the last eclipse. The column of discordances for the middle of the eclipse is satisfactory ; the other columns would indicate that the secular acceleration of the mean elongation requires an increase of less than one second , but this correction is diminished if the radius of the shadow be increased by two per cent. for the Earth's atmosphere. The result for the first eclipse may fairly be rejected, as greatly discordant from the others. The probable error seems to be about 2″ for the secular acceleration from each observed time, and the mean result is a correction of about +0″·5 to the value +6″·8 assumed in my formulæ, with a probable error of less than ±0″·5.

Ref. No.	Place.	Lat. N.	Long. E.	Date.	Local Mean Time in Degrees.	*h* = Local Sidereal Time in Degrees.	*v′*.
1*a*	Babylon	32° 26′	44° 13′	−1123 May 18	18°·819	65°·034	+538+ 931−120=
1*b*	„	32 26	44 13	−1116 June 28	334·593	61·392	+ 59−1176− 70=
1	„	32 26	44 13	−1062 July 31	297·756	56·858	−355−2518− 13=
2	Nineveh	36 24	43 0	− 762 June 15	7·693	83·720	+218+ 405− 44=
A	Heeng-yang	34 12	109 3	− 708 July 17	63·204	171·611	−238+2598+126=
3	Nineveh	36 24	43 0	− 678 June 17	305·143	23·554	+168−2064−111=
4	Susa	32 6	48 18	− 660 June 27	88·845	178·110	+ 22+2675+119=
5*a*	Larissa	36 6	43 13	− 609 Sept. 30	346·139	168·390	−864− 592+ 24=
5	„	36 6	43 13	− 602 May 18	336·329	25·786	+564−1155−122=
B	Heeng-yang	34 12	109 3	− 600 Sept. 20	68·424	241·665	−820+2728−102=
6	Iconium	37 48	32 24	− 584 May 28	103·914	164·225	+450+2695+ 86=
6*a*	„	37 48	32 24	− 556 May 19	82·962	134·541	+534+2624+ 13=
7	Athens	37 56	23 38	− 430 Aug. 3	86·327	213·240	−485+2573+ 42=
8	„	37 56	23 38	− 403 Sept. 3	320·381	117·941	−774−1584+115=
9	Rome	41 54	12 29	− 399 June 21	120·296	205·414	+ 96+2205+107=
10*a*	Thebes	38 22	23 20	− 363 July 13	329·054	75·667	−239−1345+ 2=
10*b*	„	38 22	23 20	− 360 May 12	108·734	154·886	+563+2342+ 40=
11	Syracuse	37 3	15 16	− 309 Aug. 15	310·449	89·448	−648−2061+ 89=
C	Heeng-yang	34 12	109 3	− 299 July 26	284·325	43·846	−383−2760− 40=
D	„	34 12	109 3	− 187 July 17	48·012	159·796	−275+2102+122=
E	„	34 12	109 3	− 180 Mar. 4	51·351	30·378	+775+2176− 25=
12	Utica	37 10	10 0	+ 197 June 3	23·311	94·681	+263+1025− 27=

Coming to the magnitudes, the material is greatly diminished in quantity by the fact that total eclipses are useless. The second eclipse is distinctly discordant, and so is the eighteenth, in the opposite direction, even when two thirds is taken as the observed magnitude instead of one third. Both are rejected, though the admission of both would make little difference to the result.

The tabular magnitudes were calculated without any allowance for the increment of the shadow due to the Earth's atmosphere. The most prominent fact about the differences "observed *minus* tabular" is that the observations are good enough to indicate an approximation to the accepted modern correction of two per cent. Two per cent. increment of the shadow implies an increment of 0·025 to the magnitude. In the concluding columns of the calculations a correction of 0·02 is applied. The differences "observed *minus* tabular magnitude" are then transformed into corrections to assumed secular acceleration by the factor $214 \div T^2$. The nine corrections so obtained have a range of $5''{\cdot}5$. The probable

u'	$\frac{dv'}{dt}$.	$\frac{du'}{dt}$.	$\frac{d}{dt}(V - V' - v')$ = denom. of k.	$\frac{d}{dt}(U - u')$ = num. of k.	k.	Residual $= k(V - V' - v') - (U - u')$.
$+1763 - 1111 = +652''$	$+632 + 11 = +643''$	$-119''$	$1156''$	$+296''$	+0·256	$-697''$
$+1743 - 1064 = +679$	$+601 + 25 = +626$	-134	1130	-39	−0·034	$+884$
$+1759 - 1024 = +735$	$+329 + 30 = +359$	-154	1429	-23	−0·016	$+29$
$+1955 - 1163 = +792$	$+630 + 26 = +656$	-29	1148	-149	−0·130	-42
$+1865 - 177 = +1688$	$+281 - 4 = +277$	$+275$	1551	-456	−0·294	$+211$
$+1794 - 429 = +1365$	$+343 + 5 = +348$	-226	1149	$+376$	+0·327	$+115$
$+1604 - 37 = +1567$	$+1 + 2 = +3$	$+259$	1487	-109	−0·073	$+163$
$+1960 - 239 = +1721$	$+632 - 28 = +604$	$+268$	1229	-87	−0·071	-476
$+1980 - 521 = +1459$	$+596 - 7 = +589$	-248	1286	$+433$	+0·337	$+46$
$+1882 + 1074 = +2956$	$+224 - 18 = +206$	$+133$	1651	-317	−0·192	$+429$
$+2059 - 318 = +1741$	$-154 + 20 = -134$	$+259$	2007	-74	−0·037	$+59$
$+1961 - 794 = +1167$	$+77 + 27 = +104$	$+179$	1592	-346	−0·217	$+464$
$+1918 + 594 = +2512$	$+19 - 24 = -5$	$+208$	1604	-367	−0·229	$+34$
$+1934 - 965 = +969$	$+472 - 2 = +470$	$+118$	1155	$+44$	+0·038	-525
$+2208 + 465 = +2673$	$-305 - 9 = -314$	$+225$	2130	-46	−0·022	$(+14)$
$+2063 - 1110 = +953$	$+545 + 28 = +573$	-65	1262	$+246$	+0·195	-868
$+1865 - 440 = +1425$	$-177 + 23 = -154$	$+216$	1633	-67	−0·041	$+178$
$+2013 - 1172 = +841$	$+431 + 19 = +450$	-3	1400	$+185$	+0·132	-177
$+1864 - 836 = +1028$	$+181 + 28 = +209$	-200	1614	$+20$	+0·012	-157
$+1796 - 401 = +1395$	$+413 - 0 = +413$	$+250$	1277	-417	−0·326	$+456$
$+1864 - 609 = +1255$	$+429 - 28 = +401$	-239	1417	$+59$	+0·042	$+27$
$+1879 - 1083 = +796$	$+546 + 25 = +571$	$+20$	1023	$+139$	+0·136	$+37$

error is about $\pm 1''\cdot 3$ for a single determination (corresponding to about $\pm 0\cdot 03$ in the observed magnitude) and for a mean of nine determinations we have a correction $-1''\cdot 5 \pm 0''\cdot 5$ to the value $+4''\cdot 1$ that has been adopted. The value deduced from lunar eclipses is therefore

$$+2''\cdot 6 \pm 0''\cdot 5$$

If a correction to a quantity that we know exists is obtained with a probable error one fifth part of itself, that correction is deemed well established. It is, of course, different when the existence of the quantity is in dispute. Hence it is that from the first I have admitted that the lunar eclipses are not by themselves sufficient to establish either an acceleration for the Sun or an unexpected secular acceleration for the node. But the result here obtained at least demands the examination of other evidence, such as solar eclipses, to see whether it can be confirmed.

I now come to the solar eclipses. I have first of all a few additional remarks to make about the geometry of these eclipses. In many cases the central lines, according to the present tables,

	Equation of Condition.			
1*a*	$+76(s_F - s_D) - 143 s_D =$		$-697''$	
1*b*	-76	-47	$+884$	-1062 adopted as date.
1	-73	-60	$+29$	
2	-59	$+26$	-42	
A	-56	$+129$	$+211$	Chinese.
3	$+55$	-146	$+115$	
4	$+54$	$+98$	$+163$	
5*a*	$+52$	$+93$	-476	-602 adopted as date.
5	$+52$	-142	$+46$	
B	-51	$+59$	$+429$	Chinese.
6	$+51$	$+72$	$+59$	-584 adopted as date.
6*a*	-50	$+70$	$+464$	
7	-45	$+69$	$+34$	
8	$+43$	$+25$	-525	
9	$+43$	$+54$	$(+14)$	Sun already set.
10*a*	$+42$	-49	-868	Neither date.
10*b*	$+42$	$+61$	$+178$	
11	$+40$	-19	-177	
C	-39	-44	-157	Chinese.
D	-35	$+93$	$+456$	,,
E	-35	-51	$+27$	,,
12	$+23$	-12	$+37$	

pass two or three hundred miles away from the place naturally indicated by the record. Now no admissible alterations of the tables—that is to say, alterations consistent with the observations of the last century—will produce changes of the required magnitude except changes to the secular terms of the elongation and argument of latitude. Hence every geometrical possibility is exhausted by assuming these two unknown quantities. On the other hand, it is wrong to assume that one of these quantities is theoretically zero, for facts must be examined first, and theories made later. If the theory is right, the facts will ultimately support it. Therefore, as long as it is a question of altering the central lines by two or three hundred miles, two unknown quantities are alone admissible. It turns out that these two unknown quantities suffice to reduce the residuals (or differences of latitude at apparent conjunction in longitude) to less than 50″. Further than this I cannot go, for directly it becomes a question of small corrections there is a large choice of possible alterations to the tables competent to produce them. The mean motions may be altered by 10″ or 15″ a century, but not more; the secular term in the lunar perigee may need a small correction; and of course supplementary small corrections may be given to the two principal unknown quantities.

Any formula put forward as satisfying ancient eclipses will still satisfy them if modified by the addition of

$$\lambda(25T+T^2)$$

for this quantity is not large for the epochs of the eclipses. Modern observations will ultimately settle the values of λ for the two formulæ for D and F respectively; all that can be said at present is that λ is less than 0″·5. This consideration will not

Full Calculations for the Eclipse of −708 *July* 17 *at Heeng-yang.*

$T=-25{\cdot}074254 \qquad T^2=628{\cdot}72 \qquad T^3=-15765$

	g	ω	$-\Omega$	L′	π'
Precept.					
last 4 figs.					
f centennial otion ...	− 145 280″	− 38 013″	− 73 242″	− 69 355″	−155 109″
rest of cennial motion	−43075 311 689	−541 854 629	−174 516 808	− 153°·144	...
gral number revolutions	+43075 152 000	+541 728 000	+174 960 000	...	...
lar term ...	+ 31 310	− 28 544	− 4 778	+ 3 269″	+ 1 006
e term ...	− 788	+ 694	+ 110	...	− 189
... ...	− 76° 14′ 7″	− 53° 28′ 12″	+101° 28′ 2″	−171° 30′ 4″	− 42° 51′ 32″
value at 300·0 ...	34° 5′ 31″	138° 39′ 13″	68° 11′ 41″	108° 24′ 25″	236° 38′ 15″

diminish the slight discordance that there is between the mean result of the lunar eclipses and the result of the solar eclipses, but may possibly diminish the difficulty due to the observations from 1750 to 1800.

The value of the Sun observations in their present state for the period 1750 to 1800 is not great ; possibly they are capable of improvement on re-reduction ; at present, however, they fail to stand the only test that I can apply : they give (see Newcomb's Astronomical Constants, p. 22) a wholly impossible mass of *Venus*, although the period of the *Venus* perturbations is such as to put systematic errors out of the question. The systematic mean error for the same period may easily be large. How accurately could the clocks of those days carry on the clock error from noon to the mean clock star at about 10 P.M. ? How large was the diurnal inequality in level before it was recognised as necessary to keep the shutters closed in the daytime ? Again,

Hence $F = 172° 44' 44''$, $L = 104° 33' 3''$, $D = 356° 8' 38''$ $-g' = 128° 13' 50''$.

Inequalities of Longitude.

Argument.		Coefficient.	Inequality from MS. Table.
Symbolic.	Numerical.		
	°	″	″
g	34·092	22640	+ 12 690
$-g+2D$	318·20	4586	− 3 056
$2D$	352·29	2370	− 318
$2g$	68·2	769	+ 714
$-g'$	128·2	669	+ 526
$-2F$	14·5	412	+ 104
$-2g+2D$	284·1	212	− 206
$-g-g'+2D$	86·4	206	+ 206
$g+2D$	26·4	192	+ 85
$-g'+2D$	120·5	165	+ 142
$g-g'$	162·3	148	+ 45
$-D$	3·9	125	+ 9
$-g-g'$	94·1	110	+ 110
$-2F+2D$	7	55	+ 7
$-g-2F$	340	45	− 15
$g-2F$	49	40	+ 30
$-g+4D$	310	38	− 29
$3g$	102	36	+ 35
$-2g+4D$	276	31	− 31
$g-g'-2D$	170	29	+ 5
$-g'-2D$	136	24	+ 17
			Sum = + 11 070

are we entitled to say that there are no unknown long-period terms in the motion of the Sun when we know that such terms exist in the case of the Moon? For these reasons I prefer the hypothesis of a secular acceleration of the Sun to that of a secular acceleration of the node contrary to gravitational theory.

In exhibiting the equations of condition for the solar eclipses in my first paper I gave linear equations between s_F and s_D, the corrections required by the secular terms of the argument of latitude and the elongation. Since working up the lunar eclipses it is preferable to take $s_F - s_D$ and s_D as the two fundamental quantities, because these are the quantities determined by the magnitudes and times of the lunar eclipses respectively. The coefficient of $s_F - s_D$ is $\pm 0{\cdot}0895\ T^2$, for the ascending or descending node respectively, and the coefficient of s_D is $(\pm 0{\cdot}0895 - k)T^2$.

Inequalities of Latitude.

Argument. Symbolic.	Argument. Numerical.	Coefficient.	Inequality from MS. Table.
F	172°·746	18461″	+ 2 331″
$g+F$	206·84	1010	− 456
$g-F$	221·34	1000	− 660
$-F+2D$	179·6	624	+ 4
$-g+F+2D$	130·9	199	+ 150
$-g-F+2D$	145·5	167	+ 94
$F+2D$	165·0	117	+ 30
$2g+F$	241	62	− 54
$g-F+2D$	214	33	− 18
$2g-F$	255	32	− 31
$-g'-F+2D$	308	30	− 24
$-2g-F+2D$	111	16	+ 15
$g+F+2D$	199	15	− 5
$-g'+F-2D$	309	12	− 9
			Sum = + 1 367

Parallax &c. (for numerical arguments, see inequalities of longitude).

$$p = 3423'' + 187'' \cos g + 34'' \cos (2D-g) + 28'' \cos 2D + 10'' \cos 2g$$

$$= 3423 + 155 + 25 + 28 + 4 = 3635''$$

$$p - p' = 3626''$$

$$\frac{d}{dt}(V-V') = 1632'' + 227'' \cos g + 13'' \cos 2g - 5 \cos g'$$

$$= 1632 + 188 + 5 + 3 = 1828''$$

$$-\frac{dU}{dt} = 163'' + 20'' \cos g + 2'' \cos 2g = 163 + 17 + 1 = 181''$$

Equation of centre of Sun.

$e_1' = 7324''\ \sin\ g' = -7855$ product $-5753''$
$e_2' = 82\ \sin 2g' = +97$ „ $+80$
Sum -5673
$V - V' = +2861$

$\sin\varepsilon = 4035$ $\cos\varepsilon = 9151$
Latitude $\lambda = 34°\ 12'$ $\sin\lambda = 5621$ $\cos\lambda = 8271$

G.M.T. $314°{\cdot}154$ Longitude $109°{\cdot}050$

Local Mean Solar Time $63°{\cdot}204$ $L' = 108°{\cdot}407$
Local Sidereal Time $h\ 171°{\cdot}611$ $V' = 106{\cdot}831$
$h - V' = 64°{\cdot}780$ $h + V' = 278°{\cdot}442$

Parallactic Displacements.

$(p-p')\sin\lambda\sin\varepsilon\ 822$; $\cos V'\ -290$ product -238

$(p-p')\cos\lambda\cos^2\frac{\varepsilon}{2}\ 2872$; $\sin(h-V')+9047$ „ $+2598$

$(p-p')\cos\lambda\sin^2\frac{\varepsilon}{2}\ 127$; $-\sin(h+V')+989$ „ $+126$

$v' =$ sum $= +2486''$

$(p-p')\sin\lambda\cos\varepsilon = 1865$

$(p-p')\cos\lambda\sin\varepsilon\ 1210$; $-\sin h - 1459$ product -177

$u' =$ sum $= +1688''$

$0{\cdot}2295\times(p-p')\cos\lambda\cos^2\frac{\varepsilon}{2}\ 659$; $\cos(h-V')+426$ product $+281$

$0{\cdot}2307\times(p-p')\cos\lambda\sin^2\frac{\varepsilon}{2}\ 29$; $-\cos(h+V')-15$ „ -4

$\frac{dv'}{dt} =$ sum $= +277''$

$0{\cdot}2301\times(p-p')\cos\lambda\sin\varepsilon\ 278$; $-\cos h + 989$

$\frac{du'}{dt} =$ product $= +275''$

Hence

$V - V' - v' = +375''$ $U - u' = -321''$

$\frac{d}{dt}(V - V' - v') = +1551''$ $\frac{d}{dt}(U - u') = -456''$

$k = -0{\cdot}294$

Residual $= k(V - V' - v') - (U - u') = +211''$

The Eclipse at Babylon.—Equations of condition are given for the eclipses of −1123, −1116, and −1062; and in *Monthly Notices*, lxv. p. 867, the equation of condition for −1069 with slightly different formulæ is seen to be

$$74(s_F - s_D) - 189 s_D = +655''$$

From these alternatives I select −1062 as the date of the eclipse. As to the meaning of Sivan, the equation

$$26 \text{ Sivan} = \text{July } 31$$

must be accepted, or the record must not be interpreted to mean that there was a total solar eclipse at Babylon.

The Eclipse of Nineveh.—In addition to having been recorded at Nineveh, it is clear that this eclipse was seen by the prophet Amos (see Amos viii. 9).

I have taken as the place for calculation lat. 32° 40′, long. 35° 21′.

Calculating as in other cases, I obtain

$$\begin{aligned}
v' &= +198 + 37 - 62 = +173'' & V - V' - v &= +1109'' \\
u' &= +1778 - 1187 = +591 & U - u' &= +152 \\
\frac{dv'}{dt} &= +666 + 26 = +692 & \frac{d}{dt}(V - V' - v') &= +1112 \\
\frac{du'}{dt} &= -68 & \frac{d}{dt}(U - u') &= -110
\end{aligned}$$

Hence $k = -0''{\cdot}100$, and the residual is $-263''$.

The central line therefore passed a long way to the north of Samaria according to my formulæ.

The Chinese Eclipses.—Five eclipses have been calculated for Heeng-yang. The equations of condition are

$$\begin{aligned}
-56\,(s_F - s_D) + 129\, s_D &= +211'' \\
-51\,(s_F - s_D) + 59\, s_D &= +429 \\
-39\,(s_F - s_D) - 44\, s_D &= -157 \\
-35\,(s_F - s_D) + 93\, s_D &= +456 \\
-35\,(s_F - s_D) - 51\, s_D &= +27
\end{aligned}$$

I cannot find any alteration of the formulæ or of the place of observation that will make these five eclipses all total at the same place. Our information about them is evidently deficient. They appear to be valueless, and they neither support nor conflict with any particular formulæ.

The Eclipse of Esar-haddon.—The record is perhaps satisfied if the central line intersects the line of communications between Nineveh and the Assyrian king who had gone to Egypt. The positive residual $+115''$ given by my formulæ for Nineveh shows that the central line passed south of Nineveh. I therefore do not think that this eclipse conflicts in any way with my formulæ.

The Eclipse of Susa.—This eclipse is considered by Mr. Nevill in *M.N.* lxvi. p. 411 ; it is not, however, quite apparent why he has labelled the eclipse "of Susa," for I am informed that the tablet was found at Nineveh ; and the words quoted by Mr. Nevill contain no reference to Susa. I have, however, calculated for Susa, and I find that the central line passed considerably to the south. The record is very vague, and the details unintelligible. The Sun, as Mr. Nevill points out, cannot be troubled for three days in an eclipse.

The Eclipse of Archilochus.—My formulæ supply a reasonable explanation of how it was that Archilochus saw a total eclipse. On the other hand, many other formulæ would do as much. Mr. Nevill says we have a choice of seven eclipses. Professor Millosevich excludes three of these and leaves four. In addition Archilochus is known to have lived in Paros as well as Thasos. I therefore withdraw the eclipse of Archilochus, merely congratulating myself that my formulæ do not compel me to suppose that by some curious coincidence the eclipse took place just as Archilochus had got half-way between Paros and Thasos.

The Eclipse of Larissa.—Equations of condition are given for -609 and -602. The latter date fits in with my formulæ.

Mr. Nevill's historical note on this eclipse is most valuable.

The Eclipse of Thales.—Equations of condition are given for -584 and -556 ; for the former date my formulæ make the central line pass very slightly to the south of Iconium at about $7^h\ 4^m$, or about three minutes before sunset. There is of course an uncertainty as to the exact position of the battlefield ; but this is compensated by the fact that formulæ which throw the central line much further south make it miss the mainland altogether.

If an eclipse be total just before sunset, the parts of the Sun that are first uncovered by the Moon are roughly the same as those that first disappear below the horizon. The phenomenon may thus be somewhat prolonged and to that extent more terrifying.

The Eclipse of Thucydides.—The careful language of Thucydides may advantageously be compared with his description of a partial eclipse that occurred seven years later (Thuc. iv. 52). Thucydides clearly does not describe partial eclipses as if they were total or annular. But in any case Thucydides would never have imagined the appearance of certain of the stars. He saw it. Now in *A.N.* 3682 we read that the path of this eclipse

"did not come within 500 miles of Greece." These 500 miles are, I believe, to be measured in a north-easterly direction. What does Professor Newcomb think that Thucydides was doing in the middle of the Black Sea? It is reasonable to impose the condition that Thucydides was not at any rate further off than the Bosphorus, and this limitation, to anyone who believes that the present tables correctly represent the positions of the Sun and the node, will necessitate the reduction of the secular acceleration of the Moon to its theoretical value. I however see no reason to doubt that Thucydides was in Athens, as my formulæ would make him. We know he was in Athens the following summer, when he caught the plague. He tells us on another occasion when he went on foreign service; his silence presumes that he was not on foreign service in the first year of the war. But he might, it is said, have gone to look after his estates in Thrace. If so, I do not think that he would have been so careful to explain that he was aware at this very time of the exceptional importance of the war.

"Thucydides, an Athenian, wrote the history of the war in which the Peloponnesians and the Athenians fought against one another. He began to write when they first took up arms, believing that it would be great and memorable above any previous war; for he argued that both States were then at the full height of their military power, and he saw the rest of the Hellenes either siding or intending to side with one or other of them. No movement ever stirred Hellas more deeply than this; it was shared by many of the Barbarians, and might be said even to affect the world at large." (Jowett.)

And, again, if he saw stars in the North Ægean, and if stars were not seen at Athens, he would very likely have known it.

The Eclipse of Lysander.—Perhaps no other eclipse is alluded to more slightly than this. The eclipse of −762 at Nineveh is recorded briefly, but it is recorded for its own sake. The eclipse of Lysander is recorded simply to mark the time of some events in Thrace. Fighting took place περὶ ἡλίου ἔκλειψιν. Following Mr. Nevill, I have calculated this eclipse for Athens, though I do not understand why Thrace should not be taken in preference to Athens as the place of observation. But in any case the eclipse was partial, the central line falling further north.

The Eclipse of Ennius.—To make this eclipse total before sunset, the secular acceleration must be increased largely. The record, however, does not allege totality, and in any case the authority is very slight. Cicero lived 150 years after Ennius, and Ennius lived 200 years after the eclipse.

The Eclipse of Pelopidas.—The eclipse of −363 was certainly only partial at Thebes. Oppolzer's diagrams suggested the eclipse of −360 to me, but that does not fit in either. Moreover, it would perhaps have been in conflict with current chronology that fixes the earlier date for the death of Pelopidas. The authority is Plutarch, who lived some 400 years later than the events he describes.

Moreover, the same accuracy is not to be expected of an historian who ranges over so vast a field as Plutarch as from a specialist who writes about a shorter period. On the other hand, Plutarch fills in details. He describes not only the eclipse, but the effect produced by the darkness.

The Eclipse of Agathocles.—In a footnote in *Monthly Notices*, lxvi. p. 417, Mr. Nevill points out a distinction between my two hypotheses : (i.) assigning a secular acceleration to the node different from that required by theory ; (ii.) assigning a secular acceleration to the Sun. It is perfectly true that at the same tabular time the two values of the difference of longitude will differ roughly by

$$0''{\cdot}4\ T^2 \cos g$$

In forming the residual, however, this quantity has to be multiplied by "k." The product is often negligible, but in this case it happens that it is as much as 40″. My first hypothesis, therefore, requires that Agathocles should have got to a distance of at least eighty miles from Syracuse, and my second to a distance of at least 120 miles. Both distances are perfectly possible. The account says that he only got away from the Carthaginians after dark. He was therefore in full flight for a whole day—possibly fifteen hours. Grote states that "during the night he made considerable way." In *Nature* (1906 November 2) I have discussed the historical evidence. Agathocles appears to have left Syracuse early on August 14 with a favourable wind, and there are many indications that he went northwards.

The Eclipse of Utica.—My formulæ make the eclipse of +197 total at Utica, and supply a commentary upon the words of Tertullian that does not lose its force even if it be proved that Tertullian wrote twelve years later.

Professor Newcomb says that I ignore Tertullian's "pœne." I regard my eclipse papers as proving empirical corrections removing errors from the present tables of the order $4''\ T^2$. As we cannot replace $4''\ T^2$ in the formulæ by $-100''\ T$, because such a correction is incompatible with modern observations, it follows that there is no geometrical alternative to correcting the secular terms until the errors of the present tables have been reduced from the order $4''\ T^2$ to, say, the order $0''{\cdot}4\ T^2$. When this degree of accuracy is reached small corrections may be applied, either to the secular terms or mean motions ; in fact, we get as many arbitrary quantities as equations of condition ; and hence I consider that my formulæ will only give eclipse tracks correctly to within fifty miles. I maintain that they are free from errors of 200 to 300 miles, and that the present tables are not free from such errors. Therefore, if Professor Newcomb likes, he may take the word "pœne" to mean that the central line missed Utica by a few miles. There is the further obvious alternative that "pœne" merely corresponds with the fact that there is not black darkness even on the central line of a total eclipse.

I understand Professor Newcomb to suggest (*Monthly Notices*, lxvi. p. 470) that because Airy and others deduced erroneous conclusions from ancient eclipses, therefore my conclusions will, in all probability, turn out also to be unsound. I will therefore conclude by examining the basis of Airy's conclusions. His last paper, entirely contradicting his previous paper in the *Transactions of the Royal Society* for 1853, is published in the *Memoirs, R.A.S.*, vol. xxvi. Inasmuch as his conclusion is that Hansen's tables represent the ancient eclipses that he examined, he has this in common with me, that his formulæ, as well as mine, will satisfy a century of modern observations; the same cannot be said of Oppolzer and Ginzel. Airy, however, only uses three eclipses. One of these three is the eclipse of Agathocles, where the uncertainty in the position of Agathocles causes the eclipse to satisfy nearly any formulæ; another eclipse is that of Thales, which is well known to be satisfied by Hansen's tables; and the third eclipse is that of Larissa, to which Airy assigns an impossible date. Inferences from eclipses, in view of the want of absolute precision in the records, depend upon the production of an overwhelming degree of coincidence. Airy's investigations, in reality, deduce a result from Thales, and show, as they were nearly certain to do, that the central line for Agathocles comes within one day's journey of Syracuse; and the whole degree of confirmation lies in the fact of the supposed agreement of the eclipse of Larissa, for which he has taken a wrong date. In no previous attempt to explain ancient eclipses has it ever happened that confirmation has been obtained from other eclipses. But in my case the eclipse at Babylon, the lunar eclipses, the eclipses of Thales and Larissa have all supported the explanation at which I had previously arrived from other evidence, viz. the eclipses of Nineveh, Archilochus, Thucydides, Agathocles, and Tertullian.

By what right is Airy taken as the basis for an argument that, if Airy was wrong, others too will probably be wrong? What portion of Airy's "grand labours" on the Moon, to quote a recent phrase of Lord Crawford's, survives to the present day? Is there any correct result relating to the Moon connected with his name? His measurement of the constants is most inaccurate. With a hundred years' observations at his disposal, he failed to detect any one of three short-period errors with coefficients exceeding $3''$ in his tabular longitudes; his analysis is based upon the two erroneous assumptions that his adopted solar terms are right, and that the errors of his tables depend on the position of the node. On both these points it was Mr. Nevill who got into the right path: it was he who first showed that the eccentricity of the Moon could not be determined correctly as long as certain errors in the solar terms were ignored (*Mem. R.A.S.*, vol. xlviii. pp. 315, 318), and it was Mr. Nevill who first showed that the defect of the tables was largely due to the short-period perturbations produced by the planets.

The Eclipse of Archilochus.

(*Extract from a letter from Professor E. Millosevich.*)

In the important paper on ancient eclipses of the Sun, by Mr. Nevill, *Monthly Notices*, vol. lxvi. No. 7, speaking (on p. 410) of the eclipse of Archilochus, identified by Oppolzer, by myself, and by Cowell with that of −647 April 6, total at Thasos, he says, "But this is considerably later than the date usually assigned to this poet."

The age in which Archilochus lived is determined by the fact that he mentions King Gyges of Lydia, and the catastrophe of Magnesia which occurred towards the *end* of the reign of Gyges or a *little later*. Gugu (Gyges) is mentioned as a contemporary in an inscription of the Assyrian king Assur-bani-pal, who reigned *circa* 668 to 626 B.C. The inscription is later than B.C. 662. Archilochus therefore cannot have lived before the middle of the seventh century. This is the opinion of Julius Beloch, the eminent historian of ancient Greece, from whom I had the above information.

Star Reductions. By W. Ernest Cooke, B.A.

The reduction of star places from apparent to mean positions, and *vice versa*, occupies such a large portion of observatory routine that no apology is needed for bringing before the notice of the R.A.S. a new method of attacking this troublesome matter.

If the formulæ of reduction (*Nautical Almanac*, 1906, p. 305) be examined it will be found that they may conveniently be divided into two parts :

(1) Functions of ☉ and L, and therefore of t

(2) „ „ ☊

and a few terms which may for most work be considered as negligible.

I propose that

(3) Tables be formed, giving the values of

$$A°a + B°b + C°c + D°d = K_s \text{ say}$$

and $$A°a' + B°b' + C°c' + D°d' = K_t \text{ „}$$

for each degree of N.P.D. and every 10^m of R.A., and for each tenth day throughout the year, commencing with $t = 0$ or $L = 280°$.

In this case C° and D° are computed with the elimination of terms in ☊ and 2☊, also ☾, &c.

I shall refer to these as the *Standard Tables.*

(4) In addition, an annual table is required, giving N_α and N_δ, the missing terms in ☊ and 2☊, and this is computed as follows :

Quantities x and y are tabulated for each 5° of ☊ giving

$$x = -\ \cdot 342 \sin ☊ + \cdot 004 \sin 2☊$$
$$y = -9\cdot 21 \cos ☊ + \cdot 09 \cos 2☊$$

Then $N_\alpha = cx + dy$ $\qquad$ $N_\delta = c'x + d'y$

(5) The reduction for any star is then simply the sum of the two quantities K and N, which can be taken from the tables by simple interpolation.

(6) The preparation of the Standard Tables is a rather lengthy undertaking, but the tables, when computed, will be practically correct for centuries. It will not be found so arduous as it might at first appear, because there is so much numerical repetition, with opposite signs in the different quadrants, and interpolation can be freely used.

(7) The annual table also is not a very serious affair. It must be remembered that ☊ only changes about 20° annually, and five values of t (0, 100, 200, 300, 400) are ample. In fact for many purposes two will suffice. The changes are so slight that every 2^h in R.A. and every 5° or even 10° in N.P.D. will be found sufficient for the main computation.

(8) As a matter of practice many observatories will find the computation of the annual table (even if it is not undertaken as a regular habit by the compilers of National Ephemerides) a very simple matter ; for their observations during any one year may extend over only a few degrees in declination.

(9) Take my own case. The transit work of the Perth Observatory is at present limited to the zone between −31° and −41° δ. I have prepared Standard Tables for −36°, and the variations in every case for an increase and decrease of 5° in N.P.D., computed with a simple differential formula. These tables are good for all time.

Then for each year I have to compute :

$$N_\alpha = cx + dy$$
$$I_\alpha = c_i x + d_i y$$
$$D_\alpha = c_d x + d_d y$$
$$N_\delta = c'x + d'y$$

where I_α and D_α mean the change in the annual value for an increase or decrease of 5° in N.P.D.

c and d are the ordinary values for 36°.

c_i, c_d &c. are the variation in c and d for an increase or decrease of 5° in N.P.D., &c.

I compute for 0^h, 2^h, 4^h, &c., and interpolate to half hours, and find that five values of t (0, 100, 200, 300, and 400 days) are more than sufficient.

Values of A°, B°, C°, D°, for every tenth day :

$A° = -20''\cdot47 \cos\omega \cos\odot$ $B° = -20''\cdot47 \sin\odot$

$C° = t - ''\cdot025 \sin 2L$ $D° = -\ ''\cdot551 \cos 2L$

Date.	t in Days.	A°.	B°.	C°.	D°.	3·072 C°.
Jan. 1	0	− 3·25	+20·16	·008	+·52	·026
11	10	6·46	19·22	·043	·42	·133
21	20	9·48	17·67	·076	·28	·234
31	30	12·19	15·56	·107	+·10	·328
Feb. 10	40	14·52	12·98	·134	−·08	·412
20	50	16·37	10·01	·159	·26	·488
Mar. 2	60	17·73	6·74	·181	·41	·556
12	70	18·54	+ 3·28	·201	·51	·617
22	80	18·78	− 0·26	·220	·55	·676
Apr. 1	90	18·46	3·77	·239	·52	·733
11	100	17·60	7·14	·259	·44	·795
21	110	16·22	10·32	·280	·30	·860
May 1	120	14·39	13·14	·304	−·13	·935
11	130	12·15	15·60	·331	+·06	1·017
21	140	9·60	17·61	·361	·24	1·108
31	150	6·76	19·10	·393	·40	1·207
June 10	160	3·76	20·06	·428	·50	1·314
20	170	− 0·66	20·45	·464	·55	1·423
30	180	+ 2·46	20·29	·499	·53	1·534
July 10	190	5·52	19·57	·534	·45	1·641
20	200	8·41	18·30	·568	·32	1·744
30	210	11·08	16·52	·599	+·15	1·840
Aug. 9	220	13·45	14·29	·627	−·03	1·926
19	230	15·45	11·63	·652	·22	2·004
29	240	17·01	8·66	·675	·37	2·074
Sept. 8	250	18·10	5·40	·696	·49	2·138
18	260	18·69	− 1·98	·715	·55	2·197
28	270	18·72	+ 1·49	·734	·54	2·255
Oct. 8	280	18·22	4·97	·753	·47	2·314
18	290	17·16	8·31	·774	·34	2·379
28	300	15·58	11·43	·798	−·18	2·450
Nov. 7	310	13·53	14·21	·824	+·01	2·530
17	320	11·04	16·57	·853	·20	2·620
27	330	8·21	18·42	·884	·36	2·717
Dec. 7	340	5·09	19·69	·918	·48	2·821
17	350	+ 1·82	20·37	·954	·54	2·931
27	360	− 1·50	20·41	·990	·55	3·041
37	370	− 4·79	+19·80	1·025	+·48	3·147

The figures are natural numbers, not logarithms, and it is suggested that A°a, &c., be computed with Crelle's "Rechentafeln."

Values of x and y :

$$x = -\ \cdot342 \sin \Omega + \cdot004 \sin 2\Omega$$
$$y = -9\cdot21 \cos \Omega + \cdot09 \cos 2\Omega$$

Argument Ω. (*Long. of Moon's Ascending Node.*)

Ω.	x.	y.	Ω.	x.	y.	Ω.	x.	y.	Ω.	x.	y.
°	·000	−9·12	90°	−·342	−0·09	180°	·000	+9·30	270°	+·342	−0·09
	5·8	0·8		0·2	16·0		6·0	0·6		0·4	16·0
5	−·029	−9·08	95	−·341	+0·71	185	+·030	+9·27	275	+·340	−0·89
	5·8	2·0		0·6	16·0		6·0	2·2		0·8	15·8
10	−·058	−8·98	100	−·338	+1·51	190	+·060	+9·16	280	+·336	−1·68
	5·6	3·2		1·2	15·8		6·2	3·6		1·4	15·6
15	−·086	−8·82	105	−·332	+2·30	195	+·091	+8·98	285	+·329	−2·46
	5·6	4·6		1·6	15·6		5·8	5·2		2·0	15·2
20	−·114	−8·59	110	−·324	+3·08	200	+·120	+8·72	290	+·319	−3·22
	5·4	6·0		2·2	15·2		5·4	6·4		2·4	14·6
25	−·141	−8·29	115	−·313	+3·84	205	+·147	+8·40	295	+·307	−3·95
	5·4	7·2		2·6	14·2		5·4	7·6		2·8	14·0
30	−·168	−7·93	120	−·300	+4·56	210	+·174	+8·02	300	+·293	−4·65
	5·0	8·4		3·2	13·8		5·2	9·0		3·4	13·4
35	−·193	−7·51	125	−·284	+5·25	215	+·200	+7·57	305	+·296	−5·32
	4·6	9·4		3·6	13·0		4·8	10·0		3·6	12·4
40	−·216	−7·04	130	−·266	+5·90	220	+·224	+7·07	310	+·258	−5·94
	4·4	10·4		4·0	12·2		4·4	11·2		4·0	11·6
45	−·238	−6·52	135	−·246	+6·51	225	+·246	+6·51	315	+·238	−6·52
	4·0	11·6		4·4	11·2		4·0	12·2		4·4	10·4
50	−·258	−5·94	140	−·224	+7·07	230	+·266	+5·90	320	+·216	−7·04
	3·6	12·4		4·8	10·0		3·6	13·0		4·6	9·4
55	−·276	−5·32	145	−·200	+7·57	235	+·284	+5·25	325	+·193	−7·51
	3·4	13·4		5·2	9·0		3·2	13·8		5·0	8·4
60	−·293	−4·65	150	−·174	+8·02	240	+·300	+4·56	330	+·168	−7·93
	2·8	14·0		5·4	7·6		2·6	14·4		5·4	7·2
65	−·307	−3·95	155	−·147	+8·40	245	+·313	+3·84	335	+·141	−8·29
	2·4	14·6		5·4	6·4		2·2	15·2		5·4	6·0
70	−·319	−3·22	160	−·120	+8·72	250	+·324	+3·08	340	+·114	−8·59
	2·0	15·2		5·8	5·2		1·6	15·6		5·6	4·6
75	−·329	−2·46	165	−·091	+8·98	255	+·332	+2·30	345	+·086	−8·82
	1·4	15·6		6·2	3·6		1·2	15·8		5·6	3·2
80	−·336	−1·68	170	−·060	+9·16	260	+·338	+1·51	350	+·058	−8·98
	0·8	15·8		6·0	2·2		0·6	16·0		5·8	2·0
85	−·340	−0·89	175	−·030	+9·27	265	+·341	+0·71	355	+·029	−9·08
	0·4	16·0		6·0	0·6		0·2	16·0		5·8	0·8
90	−·342	−0·09	180	−·000	+9·30	270	+·342	+0·09	360	·000	−9·12

(10) When my tables are computed—and this will in future require only about two hours' work per annum—I do not even

have to interpolate for odd minutes, because the various quantities required to correct the observed position are not applied separately to each star. Instead, a small table is computed for each day which gives :

(*a*) The sum of all corrections for -36°, and for each half hour of R.A. (clock error + reduction + $m + n \tan \zeta$ + annual precession, &c.).

(*b*) The variation for an increase or decrease of 5° N.P.D.

For this purpose the corrections K_a, N_a, K_δ, N_δ are taken direct from the tables, the only interpolation being for N considered as a function of *t*, and this is very simple.

(11) I venture to suggest that much time might be saved in future if standard tables were computed and published, and it might also be practicable to publish annual tables.

Observations of Jupiter's Sixth Satellite, from Photographs taken at the Royal Observatory, Greenwich 1906 *August.*

(*Communicated by the Astronomer Royal.*)

Photographs of *Jupiter's* sixth satellite were obtained on 1906 August 28 and August 31 with the 30-inch reflector, with exposures of 28 mins. and 45 mins. respectively. *Jupiter* and the satellite and six reference stars, whose places were derived from the Astronomische Gesellschaft Catalogue, were measured, and the following right ascensions and declinations, with the corresponding position-angles and distances, deduced :—

Date and G.M.T. 1906.	Satellite VI. App. R.A.	Satellite VI. App. Decl.	Jupiter. App. R.A.	Jupiter. App. Decl.	Deduced. Pos. Angle.	Deduced. Distance
d h m s	h m s	° ′ ″	h m s	° ′ ″	°	
Aug. 28 15 27 29	6 22 42·60	+22 37 48·1	6 23 40·85	+23 3 2·6	208·046	1715
31 15 28 32	6 54 58·69	+22 36 25·1	6 25 47·31	+22 1 58·7	203·708	1674

From the measures of *Jupiter* the apparent corrections to the tabular place are :—

	R.A.	Decl.
	s	″
Aug. 28	−·06	+2·3
31	−·11	+1·8

The deduced position-angles and distances of the satellite reckoned from the tabular place of *Jupiter* would be

	Pos. Angle.	Distance.
	°	″
Aug. 28	208·108	1713·6
31	203·781	1673·4

instead of the values given above from the direct measures of *Jupiter* and the satellite.

Further photographs are being taken at every favourable opportunity.

Royal Observatory, Greenwich:
1906 *September* 21.

Measures of Southern Binary Stars. By John Tebbutt.

The following are the results of measures of six of the most interesting binary stars of the southern hemisphere. The measures were made with the Grubb 8-inch equatorial either in sunlight or in twilight; those of position-angle with the Cooke & Sons, and those of distance with the Grubb filar micrometer. The following method was employed for each star. The star was measured on three groups of evenings, the same micrometer being employed for the first and third groups, and the other micrometer for the middle group. The means of these three sets of measures duly weighted were then taken, and the means for the first and third sets reduced to the epoch corresponding to the mean of the middle group. It may be stated that ten measures at least in each coordinate were taken of each star on each night of the groups.

Star.	Epoch.	Position-angle.	Distance	No. of Evenings for Position-angle	No. of Evenings for Distance.	Hour Angle.
p Eridani ...	1906·161	219°·8	8″·90	4	4	W.
γ Centauri ...	1905·471	352·9	1·52	8	6	E. & W.
β Muscæ ...	1905·726	345·0	1·33	6	3	W.
α Centauri ...	1905·476	212·1	21·16	7	12	W. & E.
β 416 ...	1905·618	279·3	2·38	4	4	E.
γ Coronæ Aust. ...	1905·650	123·5	1·69	6	4	E.

Observatory, Peninsula, Windsor, N.S. Wales:
1906 *July* 17.

Ephemeris of Flora near the time of Opposition in 1907.
By A. M. W. Downing, D.Sc., F.R.S.

This ephemeris is computed from Brünnow's "Tafeln der Flora," in combination with the corrected continuation of certain of the tables published in *Monthly Notices*, vol. lxiv. No. 6.

Berlin Midnight.	Apparent R.A.	Apparent Dec.	Log. Distance from Earth.
1907.	h m s	° ′ ″	
Jan. 4	7 47 3·26	+20 56 47·6	0·03832
5	45 56·64	21 3 36·8	·03814
6	44 49·22	10 25·9	·03807
7	43 41·11	17 14·6	·03811
8	42 32·42	24 2·4	·03825
9	41 23·26	30 48·9	·03850
10	40 13·75	37 33·8	·03885
11	39 4·02	44 16·5	·03931
12	37 54·17	50 56·7	·03987
13	36 44·33	21 57 34·0	·04054
14	35 34·63	22 4 7·9	·04131
15	34 25·19	10 37·9	·04218
16	33 16·14	17 3·6	·04315
17	32 7·58	23 24·5	·04423
18	30 59·63	29 40·2	·04541
19	29 52·41	35 50·4	·04669
20	28 46·02	41 54·9	·04807
21	27 40·57	47 53·4	·04954
22	26 36·15	53 45·6	·05110
23	25 32·86	22 59 31·3	·05276
24	24 30·81	23 5 10·4	·05451
Jan. 25	7 23 30·09	+23 10 42·6	0·05635

Magnitude at Opposition, January 13 = 8·6.

LIST OF ADDITIONS

TO THE LIBRARY

OF THE SOCIETY

JUNE 1905 TO JUNE 1906.

An asterisk (*) indicates that the work is an excerpt.

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